AN APPARATUS FOR MEASURING RADIAL DISPLACEMENT OF A WHEEL

RELATED APPLICATION

[00001] The subject patent application claims priority to and all the benefits of U.S. Provisional Patent Application Serial No. 60/446,464 filed on February 11, 2003.

FIELD OF THE INVENTION

[00002] This invention relates generally to a system for measuring radial displacement of a wheel having two beads for engaging a tire.

BACKGROUND OF THE INVENTION

[00003] Motor vehicles are commonly supported by pneumatic tires supported on the respective wheels. It is well known that non-uniform tire and wheel assemblies contribute significantly to noise and vibration of the motor vehicle. A common cause of noise and vibration is the tire and wheel assembly that is not substantially round, which results in what is commonly referred to as smooth road shake, resulting in the undesirable vibration of the motor vehicle. To improve the potential for manufacturing the tire and wheel assembly that is substantially round, the concentricity of the tire and of the wheel is determined prior to assembling the tire with the wheel. To produce a substantially round tire and wheel assembly, the tire is aligned upon the wheel so that a maximum wheel deviation is aligned with a minimum tire deviation, causing the two deviations to cancel out. During the assembly process, the concentricity of the wheel

is measured, and the maximum deviation is marked with a die. Likewise, the concentricity of the tire is measured and a minimum deviation is marked with a die. While mating the tire to the wheel, the markings are aligned so that the maximum wheel deviation and the minimum tire deviation are positioned adjacent, attempting to cancel out the tire and wheel deviations.

[00004] Manual measurement of the concentricity and radial displacement of the wheel can be time consuming and subject to human error. It has become desirable to process an ever-increasing variety of the wheels, through a single workstation. The art is replete with various workstations and apparatuses for measuring the concentricity of a wheel. The United States Patent Nos. 3,951,563 to Ravenhall; 5,074,048 to Yokomizo et al.; and 6,173,213 to Amiguet et al. teach various devices and workstations for measuring concentricity of wheels.

[00005] The United States Patent No. 3,951,563 to Ravenhall, for example, teaches a device for measuring the radial displacements of upper and lower beads of a wheel. The device includes separate sensors that are placed against each bead of the wheel, being axially rotated to measure the wheel's radial displacement. The measurements of the upper and lower beads are converted into step impulses by an encoder, which are subsequently fed into a digital computer. The sensors are designed to measure the radial displacement of the respective upper and lower beads with respect to the axis of the wheel. The signals produced by each sensor are transformed to the digital computer via a digital converter. The signals are converted and forwarded to the computer by an encoder, which correlates each step input to a particular angle of rotation of the wheel. The sensors require separate calibration.

[00006] In addition to the aforementioned patents, the related art teaches various other devices, which are presently used to determine radial displacement of the

wheel. One such device generates a visual analysis conducted by a machine of the two surfaces that mate with the beads of a tire. This type of device is known to be expensive and difficult to calibrate, because two electronic mechanisms are required to measure radial displacement of each of the two surfaces, i.e. upper and lower beads that mate with the respective tire beads. Other devices are known to use mechanical measurements, but still require two measuring instruments for each of the two surfaces that mate with the tire beads. Therefore, the aforementioned devices are also difficult to calibrate.

[00007] There is a constant need in the area of the automotive industry for an improved system for measuring radial displacement of a wheel. Therefore, it would be desirable to produce an apparatus for measuring radial displacement of a wheel that is simple to manufacture and easy to calibrate.

SUMMARY OF THE INVENTION

[00008] An apparatus for measuring radial displacement of a wheel having first and second beads each having a peripheral surface circumscribing an axis, includes a mount assembly for rotating the wheel around said axis. A sensing device of the apparatus is movable radially relative to the axis. A bead engaging element is pivotably connected to the sensing device for simultaneously engaging the first and second beads. The bead engaging element moves the sensing device with respect to the axis as the first and second beads vary in radial distance from the axis around the wheel. The moving motion of the sensing device, when the sensing device moves radially relative to the axis, facilitates detection of the combined offset of the first and second beads from the axis to generate a first signal representing the average radial displacement of the first and second beads.

[00009] An advantage of an inventive sensor of the present invention is to provide an apparatus to solve the problems associated with the prior art devices for measuring radial displacement of a wheel by virtue of its simplistic design, wherein a bead engaging element pivotably connected to a sensing device detects the combined offset of first and second beads of the wheel from an axis.

[00010] Another advantage of the present invention is to provide an apparatus having a single sensor operably connected to the bead engaging element, thereby eliminating prior art dual sensors design, each of which must be calibrated in order to accurately determine the radial displacement of the wheel.

[00011] Therefore, a software performing calculations is simplified relative to a software performing calculations associated with the prior art dual sensor design.

[00012] Further, because only one sensor needs to be calibrated, the accuracy of measurements is increased unlike the prior art dual sensor design, which introduces measurement variability by virtue of making two measurements.

BRIEF DESCRIPTION OF THE DRAWINGS

[00013] Other advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[00014] Figure 1 is a sectional side view of an apparatus for measuring radial displacement of a wheel;

[00015] Figure 2 is a top and partially cross sectional view of a motor mount assembly for the apparatus;

[00016] Figure 3 is a cross sectional fragmental view of a sensor tower of the apparatus having a horizontal member operably connected with a vertical member and presenting abutting engagement with the wheel;

[00017] Figure 4 is a perspective and partially broken view of the sensor tower having the vertical member diverging with respect to the horizontal member;

[00018] Figure 5 is a perspective and partially broken view of an actuator operably connected to the sensor device, wherein the sensor tower is moved away from a mount device holding the wheel; and

[00019] Figure 6 is another perspective partially broken view of the actuator operably connected to the sensor device, wherein the sensor tower is moved to the mount device holding the wheel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[00020] Referring to Figure 1, wherein like numerals indicate like or corresponding parts, an apparatus of the present invention is generally shown at **10**. The apparatus **10** determines radial displacement of a wheel **12** having upper **14** and lower **16** beads each presenting a peripheral surfaces **18**, **20** circumscribing an axis **A**, and first radius **R1** and second radius **R2** of the upper **14** and lower **16** beads, defined between the axis **A** and the peripheral surfaces **18**, **20**. The apparatus **10** presents a support frame, generally shown at **22**, having a work surface **24** having upper **26** and lower **28** sides, front **30** and rear **32** ends. A wall **34** is connected to the work surface **24** at the rear end **32**. A plurality of mounting members, i.e. legs **36** are connected to and extend from the lower side **28** of the work surface **24** to secure the support frame **22** onto a floor **38**.

[00021] A mount assembly, generally indicated at **40**, over which the wheel **12** is secured, is operably connected to the work surface **24** for rotating the wheel **12**

about the axis **A**. The mount assembly **40** includes a spring mount **42** axially aligned with a spindle plate **44**. The wheel **12** is supported by the spindle plate **44** and secured to the mount assembly **40** by the spring mount **42**. The spring mount **42** includes a plurality of slots (not shown) located radially about the spring mount **42** much like a collet. Disposed within the spring mount **42** is a bladder **46** or equivalent inflatable member providing an enclosure capable of being de-pressurized, thereby retract the spring mount **42** radially inwardly to allow the wheel **12** to slide freely over the spring mount **42**. Otherwise, the spring mount **42** is biased radially outwardly to securely engage the wheel **12**. The mount assembly **40** is supported by a spindle **48** projecting upwardly from the work surface **24**. A motion device **52**, i.e. motor is disposed beneath the work surface **24** to provide radial movement to the mount assembly **40** and therefore the wheel **12**.

[00022] As best shown in Figure 1 and 2, a motion device **52**, i.e. motor is disposed beneath the work surface **24** to provide radial movement to the mount assembly **40** and therefore the wheel **12**. The motor **52** presents an axis **B** and is suspended from the work surface **34** by a pivotable motor mount **54** presenting an axis **C**. A motor arm **56**, defined by a plate, extends from the motor mount **54** and is operably connected with the motor **52**. The motor arm **56** is pivotable around the axis **C** defined by the motor mount **54**. Therefore, the location of the motor **52** may be altered as needed. A pulley **60** circumscribing the axis **B**, is rotationally driven by the motor **52** to provide driving motion to a belt **62**. The belt **62** transfers rotational movement from the motor **52** to a second pulley **64**, which in turn transfers rotational movement to a shaft **66**. The shaft **66** transfers rotational movement to the spindle **48** of the mount assembly **40**, which in turn transfers rotational movement to the wheel **12**. Tension of the belt **62** is

maintained by virtue of pivotal movement of the motor **52** with respect to axis **C** of the motor mount **54**. An adjustable block **68** presents an axis **D** and is operably connected to the work surface **24**. A lever **70** extends from the adjustable block **68** in a cantilevered fashion. A link **72** is rotatably connected to the motor arm **56**. The link **72** includes a cylindrical core **74** cooperably connected to the link **72**. The cylindrical core **74** is slidably movable along the lever **70** to move the motor arm **56** toward and away from the second pulley **64** to secure the motor **52** in the desired position. The cylindrical core **74** includes mechanical means (not shown) for securing the link **72** with the lever **70** at the desired position. Therefore, the belt **62** is easily replaced.

[00023] A second sensor, i.e. encoder **78** is axially aligned with the shaft **66** and is supported by an encoder bracket (not shown). The encoder **78** tracks a phase angle, i.e. rotational location of the wheel **12** to identify the exact location of the wheel deviation, i.e. radial displacement. The encoder **78**, coupled to the spindle **48** detects a phase angle of rotation of the spindle **48**. The encoder **78** operates as is known to those skilled in the art of radial location determination. The encoder 78 is electronically connected to a controller **79**.

[00024] Referring to Figures 3 and 4, a supporting element, i.e. sensor tower, generally shown at **80**, will now be discussed. The sensor tower **80** is defined by a frame **82** having side walls **84**, **86** presenting upper **88**, **90** and lower **91**, **92** ends, respectively. A top portion **94** of the sensor tower **80** extends between the side walls **84**, **86** at the upper ends **88**, **90** interconnecting one with the other. A support plate **96** extends between the side walls **84**, **86** interconnecting one with the other for supporting a sensing device, i.e. horizontal member, generally indicated at **98**, slidably disposed on

the support plate **96** and a bead engaging element, i.e. vertical member, generally indicated at **100**, pivotably connected to the horizontal member **98**.

[00025] The vertical member **100** extends perpendicularly with respect to the horizontal member **98.** diverging therefrom in response to the radial displacements of the upper and lower beads **14**, **16**, respectively, as an offset between the upper **14** and lower **16** beads results from a difference in length between the first radius **R1** and the second radius **R2** of the upper bead **14** and the lower bead **16** with respect to the axis **A,** as the upper **14** and lower **16** beads vary in radial distance from the axis **A** around the wheel **12**.

[00026] As best shown in Figure 4, the vertical member **100** includes a pair of plates **102**, **104** presenting extremities **106**, **108**, **110**, and **112**, respectively. The plates **102**, **104** are spaced apart by a core member **114** for facilitating the pivotable connection with the horizontal member **98**. The vertical member **100** is pivotably connected to the horizontal member **98** to simultaneously engage the upper **14** and lower **16** beads. The vertical member **100** moves the horizontal member **98** with respect to the axis **A** through mechanical motion of the vertical member **100** in response to difference between the radial displacements of the upper **14** and lower **16** beads, as the upper **14** and lower **16** beads vary in radial distance from the axis **A** around the wheel **12**.

[00027] A pair of support tips **116**, **118** having necks **120**, **122**, respectively, are disposed between and are connected to the plates **102**, **104** at each of the extremities **106**, **108**, **110**, **112**, respectively. A pair of rollers **124**, **126**, i.e. feelers are pivotably connected to the respective support tips **120**, **122** for facilitating the abutting engagement of the vertical member **100** with the upper **14** and lower **16** beads of the wheel **12**. The location of the radial displacement of the respective upper **14** and lower

16 beads of the wheel **12**, as determined by the encoder **78**, is signaled to the controller **79** through a cable (not shown).

[00028] The horizontal member **98** includes a pair of spaced walls **130**, **132**. A pair of shafts, only one is shown at **134** in Figures 3 and 4, have terminal ends **136**, **138**. Each shaft **134** is connected to the side walls **84**, **86** of the support structure **82** of the sensor tower **80** at one terminal end **136** and is slidably connected to the horizontal member **98** at another terminal end **138**. A resilient member **140**, i.e. spring, is annularly engaged about each shaft **134** and disposed between the terminal ends **136**, **138** of each shaft **134**. The spring **140** generates biasing force, thereby biasing the vertical member **100** via the horizontal member **98** against the wheel **12**. While only the aforementioned spring **140** has been discussed, biasing force may be generated by various devices, or equivalents as known to those of skill in the art.

[00029] A link **142**, extends between the walls **130**, **132** of the horizontal member **98**, interconnecting the walls **130**, **132**. A projection member **144** is connected to the link **142**. A pin **143**, extending through the walls **130**, **132**, plates **102**, **104**, and the core portion **114**, facilitates pivotable motion of the vertical member **100** with respect to the horizontal member **98**. A pair of bushings **145** surround the pin **143** to prevent radial disposition of the vertical member **100** relative to the horizontal member **98**.

[00030] A first sensor, i.e. linear variable differential transformer (LVDT), generally indicated at **146**, is connected to and extends from the projection member 144. The LVDT **146** is operably connected to the controller **79**. The LVDT **146** presents a sensitive measuring device that produce an electrical output signal precisely proportional to the mechanical displacement of the vertical member **100** mechanically connected to the horizontal member **98**. Based on the linear variable differential transformer (LVDT)

principle, the performance of the LVDT **146** depends on inductance effects that do not involve flexing wires or sliding electrical contacts. The LVDT **146** includes various components not shown in the present invention, such as, for example coils, which are magnetically shielded, and are cased in hardened stainless-steel housings. The LVDT **146** has an internal spring to continuously push an armature presenting a probe end to its fullest possible extension, thereby maintaining light yet reliable contact with a measured object, i.e. the wheel **12**. The LVDT **146** produce an AC output voltage proportional to the mechanical displacement of a small iron core. One primary and two secondary coils are symmetrically arranged to form a hollow cylinder. A magnetic nickel-iron core, i.e. core, supported by a nonmagnetic push rod **148**, moves axially within the cylinder in response to mechanical displacement of the horizontal member **98**. With excitation of the primary coil, induced voltages will appear in the secondary coils. Because of the symmetry of magnetic coupling to the primary, these secondary induced voltages are equal when the core is in the central, i.e. null or electric zero position. When the secondary coils are connected in series opposition, the secondary voltages will cancel and ideally there will be no net output voltage. If, however, the core is displaced from the null position, in either direction, one secondary voltage will increase, while the other decreases, thereby producing an output conforming to the accurate characteristic.

[00031] Referring to Figures 5 and 6, a carriage, generally indicated at **150**, moves the sensor tower **80** to and from the wheel **12**. The carriage **150** is operably connected to the side walls **84**, **86** at the lower ends **91**, **92** for moving the sensor tower **80** to and from abutting engagement with the wheel **12**. The carriage **150** presents a pair of tracks **152** (only one is shown), defined therein. A pair of integrated rails, generally indicated at **156**, are connected to the work surface **24**. Each rail **156** presents first **158**

and second **160** ends and a surface complementary to the surface of the tracks **152** for facilitating a slidable motion of the carriage **150** along the rails **156**.

[00032] A pneumatic actuator, generally indicated at **161**, is operably connected to the carriage **150** for moving the sensor tower **80** to and from the mount assembly **40**. The pneumatic actuator **161** presents a housing **162** that includes a rod **164** having first **166** and second **168** ends, a piston **170**, connected to the rod **164** at the first end **166**. An anchor device **172** is connected to the work surface **24** extending outwardly therefrom. The anchor device **172** is connected with the second end **168** of the rod **164** for facilitating slidable movement of the sensor tower **80** to and from the mount assembly **40**. Inward and outward ports (not shown) are defined in the housing **162**. Inward and outward pressure lines (not shown) are operably connected to the inward and outward ports, respectively. The outward pressure line pulls air out of the housing **162** reducing air pressure, i.e. P1 inside the housing **162** thereby moving the piston **170** inwardly. In addition, the inward pressure line forces air into the housing **162** increasing the air pressure, i.e. P2 inside the housing **162** thereby moving the piston **170** outwardly. If P1 is higher than P2, the rod **164** is pushed outwardly from the housing **162**, thereby moving the sensor tower **80** away from the mount assembly **40**. However, if P1 is less than P2, the rod **164** is pulled inwardly to the housing **162**, thereby moving the sensor tower **80** to the mount assembly **40** for facilitating the abutting engagement of the vertical member **100** with the upper **14** and lower **16** beads of the wheel **12**. While only the aforementioned pneumatic actuator **161** have been discussed, P1 and P2 may be generated by spring devices, or equivalents, such as, for example, hydraulic, and electronic devices, as known to those skilled in the art.

[00033] Referring back to Figures 5 and 6, a stopper device **180** is connected to the work surface **24** extending upwardly from the work surface **24**. The stopper device **180** is engaged at the first end **158** of the integrated rails **156** for controlling a stroke of the sensor tower **80** with respect to the mount assembly **40**. The stopper device **180** includes a finger **182** having a resilient head **184** to facilitate frictional engagement with the sensor tower **80**. In addition to the stopper **180**, a pair of positioning bars, only one is shown at **186** in Figures 1 and 3, opposed one the other, may be included to secure the wheel **12** in a desired location upon the mount assembly **40** so that the sensor tower **80** can engage the upper **14** and lower **16** beads by forming a V-block to receive the wheel **12**, as best shown in Figures 1 and 3. The positioning bars **186** also protect the sensor tower **80** from being damaged while positioning the wheel **12** upon the mount assembly **40**. The positioning bars **186** extend upwardly from the work surface **24** generally between the mount assembly **40** and the sensor tower **80**. To locate the wheel **12** accurately upon the mount assembly **40**, the wheel **12** is positioned in an abutting relationship with the positioning bars **186**, which locates a central aperture of the wheel **12** directly above the mount assembly **40**. Once the wheel **12** is positioned in abutting relationship with the positioning bars **186**, the wheel **12** can be lowered into engagement with the mount assembly **40**.

[00034] An applicator, i.e. tool for marking the upper bead **14** of the wheel **12** is shown at **190** in Figure 1. The tool **190** is operably connected to the top portion **94** and is operably connected to the controller **79** for receiving a forth signal for placing a mark onto the upper bead **14** of the wheel **12**. A die reservoir **192** is supported by reservoir bracket **194** that is mounted on the wall **34**. The die reservoir **192** is fluidly connected to a die nozzle **196** by a hose or tube **198**. The die nozzle **196** points

downwardly from above the wheel **12** to apply a marking of die to the wheel **12** surface at a desired location. While only the aforementioned tool **190** for placing the mark, i.e. paint based mark, have been discussed, the mark may be placed by drilling, or other methods, known to those skilled in the art.

[00035] The controller **79** is disposed upon an opposite side of the wall **34**. The controller **79** is in electronic communication with the mount assembly **40**, the motion device **50**, the encoder **78**, the sensor tower **80**, the LVDT **146**, and die nozzle **196**. The controller **79** includes a computer having an input/output interface, a central processor unit, a random access memory, i.e. RAM, and a read only memory, i.e. ROM. The input interface is electrically connected with the mount assembly **40**, the motion device **50**, the encoder **78**, the sensor tower **80**, and the LVDT **146**. Signals from the LVDT **146** and the encoder **78** are fed into the computer through the input interface and are temporarily stored in the RAM. The ROM stores a program, i.e. first comparative software for calculating radial displacements of the upper **14** and lower **16** beads of the wheel **12** and reads out these programs from the ROM and various data from the RAM and carries out the calculation. The controller **79** includes a second comparative software for integrating a reference signal, i.e. phase angle over a 360 degree rotation of the wheel **12**, generated by the encoder **78**, and to determine a comparison with a previously stored value, i.e. the highest negative and the highest positive value with respect to the null position, generated by the LVDT **146**. The second comparative software integrates the first and second signals and generates a third signal, i.e. determination of a median between the radial displacements of the upper **14** and lower **16** beads of the wheel **12**. The third signal represents the average radial displacement of the upper **14** and lower **16** beads relative to the axis **A**. The third signal further directs

the mount assembly **40** to rotate the wheel **12** in a way, wherein the aforementioned median between the upper **14** and lower **16** beads is placed right below the tool **190** for the mark to be placed on the upper bead **14**. The comparative software generates a forth signal and translates the forth signal to the tool **190** for placing the mark.

[00036] During operation, the wheel **12** is located on the mount assembly **40** by abutting the wheel **12** against the opposing positioning bars **186**. Once located, in the desired position, the wheel **12** is lowered onto the mount **12** and rested upon the spindle plate **44**. The vacuum on the spring mount **42** then released allowing the spring mount **42** to spread outwardly, increasing its diameter to secure the wheel **12** to the mount **12**. Once the wheel **12** is in position on the mount **12**, the radial displacement measuring cycle is initiated and the wheel **12** is pivoted by the motor **48** as described above. The sensor tower **80** is moved to the wheel **12** by the carriage **150**, whereby the vertical member **100** simultaneously engages the upper **14** and lower **16** beads of the wheel **12**. The resilient device, i.e. spring **140**, operably connected to the horizontal member **98**, biases the vertical member **100** against the wheel **12** to ensure constant simultaneous contact of the vertical member **98** with the upper **14** and lower **16** beads during rotational cycle of the wheel **12**. The rollers, i.e. feelers **124**, **126**, rotatably connected to the vertical member **100**, translate motion of radially displaced upper **14** and lower **16** beads to the push rod **148** through the horizontal member **98** operably connected to the push rod **148**. The push rod **148** is operably connected to the LVDT **146** and is movable to and from the LVDT **146** to determine two highest reading, positive and negative with respect to the central, i.e. null position determined by the LVDT **146**. At the same time, the encoder **78** tracks and signals to the controller **79** the first signal, i.e. phase angle or segment of rotational movement of the wheel **12**. The first comparative

software of the controller **79** receives both the highest positive and the highest negative readings from the LVDT **146** and each reading of the segment of rotational movement from the encoder **78** to complement each of the highest negative and positive readings with the respective phase angle. The second comparative software averages the two readings with the respective phase angles to determine a median deviation, i.e. averaged point of the radial displacements between the upper **14** and lower **16** beads. When the median deviation is detected, the mount assembly **40** rotates the wheel **12** to position, whereby the median deviation is oriented below the die nozzle **196** of the tool **190**. The controller **79** signals the die nozzle **196** to apply die onto the upper bead **14** of the wheel **12** at the location of the median deviation. After the median deviation has been marked with the die, the spring mount **42** is depressurized, thereby decreasing the diameter of the spring mount **42** allowing the wheel **12** to be removed from the assembly **10**.

[00037] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.